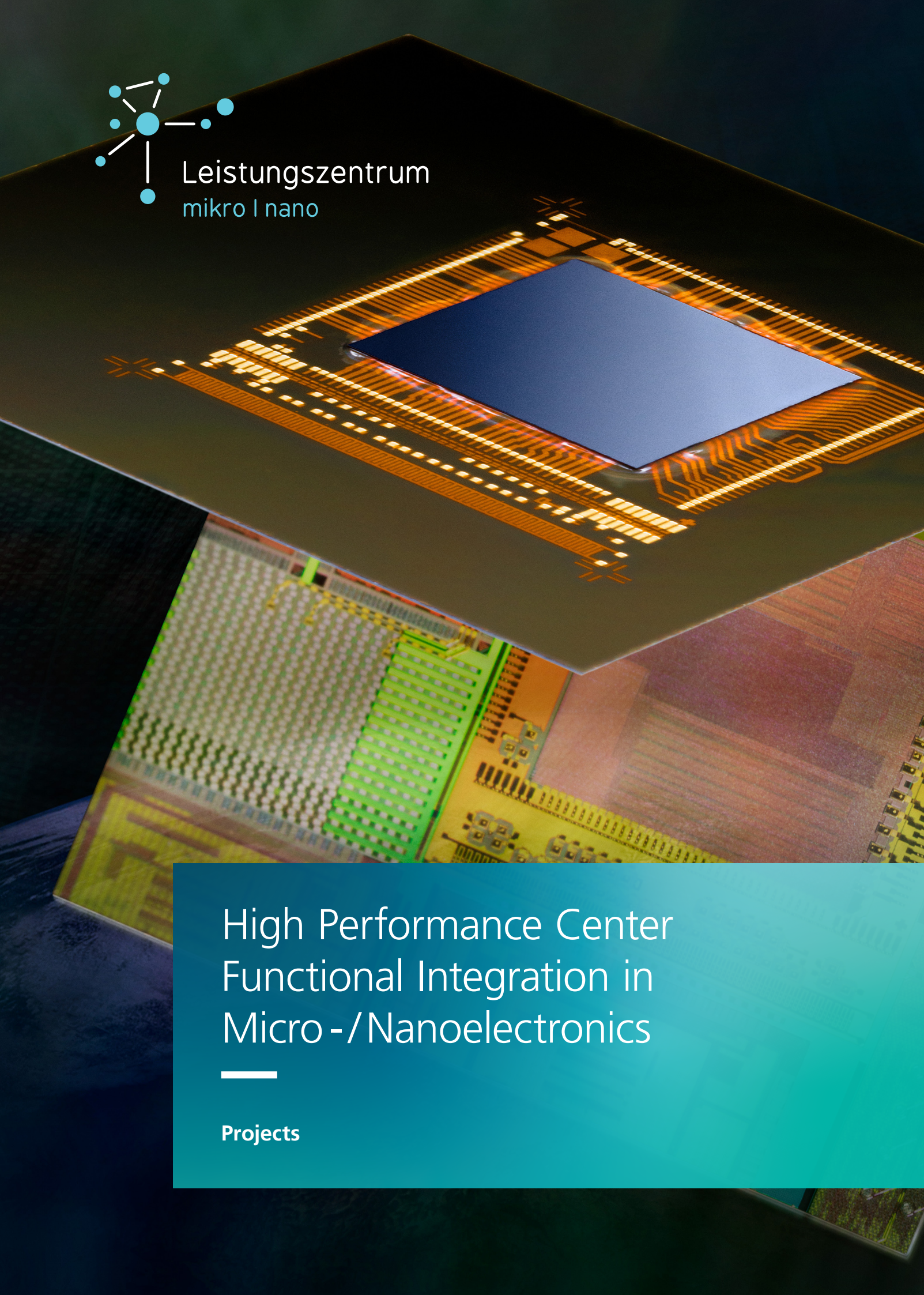


Leistungszentrum
mikro I nano

# High Performance Center Functional Integration in Micro-/Nanoelectronics

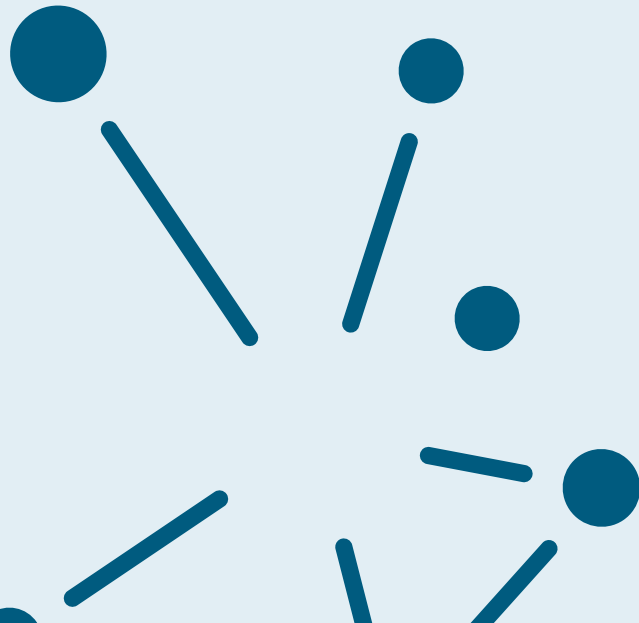
**Projects**

# Enabling New Functionalities in Micro- and Nanoelectronics

High Performance Centers are a joint initiative of Fraunhofer institutes, universities and other non-university research institutes with the goal of transferring the results of excellent applied research to industry partners. Such centers have a clear topical as well as geographical focus, i.e. the participating research partners are located in the same region within Germany.
The High Performance Center »Functional Integration in Micro- and Nanoelectronics« combines the competences of the Fraunhofer Institutes IPMS, ENAS, IIS-EAS and IZM-ASSID, which are well aligned along the value chain of microelectronics and microsystems R&D. Additionally, these competences are complemented by the expertise available at institutes of the Dresden University of Technology, Chemnitz University of Technology and the Dresden University of Applied Sciences. We employ this portfolio of competences to address the following R&D segments of high relevance for our industry partners:

- Novel materials enabling new functionalities
- Modular heterogeneous wafer systems
- Platform technology for ultrasonic sensors
- Integrated spectrometers and other optical systems employing nanostructured materials
- Sensors and actuators for integration into machine tools
- Design of safety-critical systems

The close cooperation between the Fraunhofer institutes and research groups at the said universities ensures a fast transfer of generated basic knowledge and newly developed core technologies to applied research and development.
The High Performance Center offers application- and customer-specific development as well as small series production of components, integrated circuits and system-in-package (SiP-) solutions for sensors and actuators. Cross-institutional use of R&D-expertise and –infrastructure enables systems solutions and demonstrators for sensors and actuators for e.g. the industrial internet of things (IIoT), a key to “Industry 4.0”



# Expanding the Joint Technology Platform

The High Performance Center »Functional Integration in Micro- and Nanoelectronics« (Center Micro/Nano for short) constitutes a unique platform across the participating institutes for the core competences

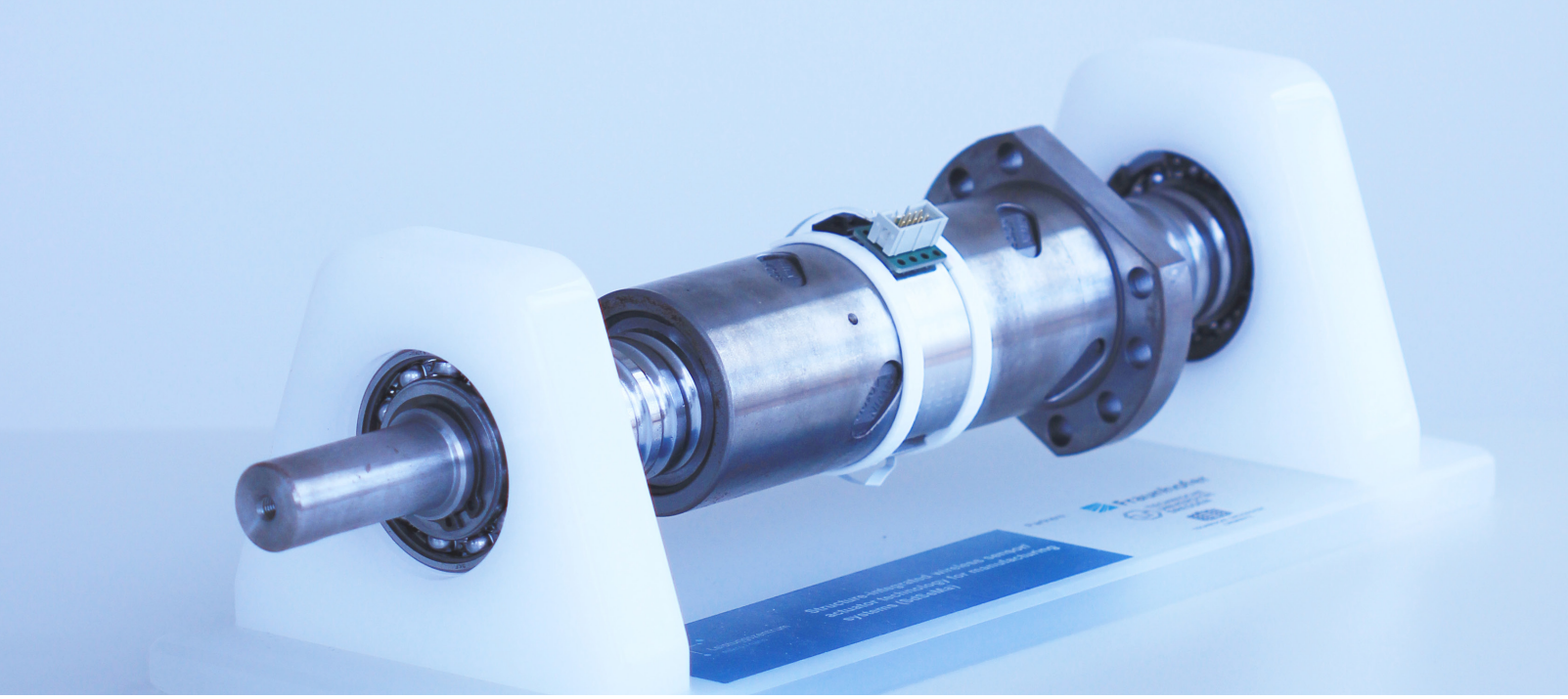
- Systems design & integration
- New functional materials
- Components and related fabrication technologies
- Assessment of reliability.

The Center Micro/Nano, established in 2016 and funded by the Free State of Saxony and the Fraunhofer Society, has always used these competences to continuously expand its capabilities, now being able to offer the below listed technology platforms for customer specific R&D:

- Structure-integrated wireless sensors for machine tools
- Platform for micromechanical ultrasonic transducers (MUT)
- Modular integration of thin heterogeneous sensor systems
- Test wafer hub – platform offering 300 mm test wafers for wafer-based technologies and products.

In the field of structure-integrated sensors and actuators for machine tools and manufacturing systems, there is currently a significant technology push, driven by advances in micro- and nanoelectronics as well as microsystems technology, into machine tool construction and industry. Non-contact ultrasound-based sensing gains importance in particular for sensors needed in the context of Industry 4.0. Thereby, silicon MEMS-based (microelectromechanical systems) ultrasonic transducers (MUT) offer significant advantages and open new paths to build complex multi-element sensor systems, which will allow e.g. 3D room survey.

For the cost-effective production of such microelectronics and MEMS based sensor systems from medium to large scale, wafer-based fabrication and modular integration technologies are required, covering wafer sizes up to 300 mm. The last two of the above listed technology platforms exactly address these topics, completing the portfolio of competences available at the Center Micro/Nano.



## Structure-integrated wireless Sensors for Machine Tools

For a self-organizing, user-oriented and demand-driven automated production (Industry 4.0), a large variety of connected, structure-integrates sensors and actuators will be required. These devices have to be robust with a small form factor and should be able to communicate via wireless data links.

A promising approach towards that goal is the functional and structural integration of microelectronic and micromechanical devices and subsystems into machine tools and components of manufacturing systems.

It is often challenging to achieve process-control via condition monitoring when relevant components are located at hardly accessible positions inside the machinery. Therefore, miniaturized, cross-linked, and energy-efficient data acquisition, data processing and data transmission technologies have to be implemented and integrated directly into the structures of mechanical drives and machine tools.

A joint research team from the High Performance Center and Fraunhofer IWU collaborates on the conception, engineering and test of structure-integrated sensor and actuator systems in machine parts. Hereby, as an exemplary use case, we added an integrated wireless sensor node to a ball screw drive in a tooling machine, enabling process control and status monitoring.

## Project Details

**Concept**

- Providing a technology development platform to enable smart "Industry 4.0" functionalities in mechanical engineering systems by implementing sensors and actuators
- Functional integration of microelectronic and micromechanical devices and subsystems into components of manufacturing systems
- Upgrading existing machinery to "Industry 4.0" standard by retrofitting with "intelligent" components and modules
- Exemplary use case: "intelligent" ball screw drive with built-in sensor ring

**R&D objectives**

- Full structural integration of all key electronic components through rigorous miniaturization
- Wireless data transmission out of a metal shielded environment
- Power supply and management for wireless IoT solutions
- Improved functionality, robustness and reliability
- Integration of "intelligence": data processing in sensor node enabling AI functionalities
- Variability of form factor to fit into an existing mounting space

**Added value**

- Increase of the overall equipment effectiveness (OEE)
- Condition-dependent scheduling of maintenance intervals
- Improved insight into production processes

**Targeted applications**

- Condition monitoring
- Predictive maintenance
- Adaptive process control


## Platform for Micromechanical Ultrasonic Transducers

MEMS-based micromechanical ultrasonic transducers (MUT) offer significant advantages compared to conventional transducers based on established piezo-ceramics or composite materials. Silicon-based MUT-devices can be realized with a small footprint and mass-produced at low cost, while being compliant with the RoHS directive. MUT technology allows the convenient fabrication of multi-channel arrays, for e.g. imaging or flow measurement imaging, as well as flexibility in the choice of the operating frequency for an optimal trade-off between detection range and sensitivity.

With the setup of a technology platform for MUT ultrasonic transducers the High Performance Center »Functional Integration for Micro- and Nanoelectronics« helps to further advance the development and the market introduction of MEMS-based ultrasonic transducers. The Center's offering ranges from the realization of compact sensor systems based on this technology to the development of related fabrication technologies up to marketing support for different target applications. Furthermore, we provide MUT evaluation kits to give interested partners and customers easy and effective hands-on access to our highly integratable technology.

Potential application areas are factory automation, automotive sensors and medical diagnostics. Image generating MUT sensor systems are applicable to endoscopic high-resolution imaging. When used in spirometers or industrial flow meters, MUTs enable portable devices for precise gas flow measurements. Industrial robots and autonomous vehicles can be enabled to gather information on their surrounding including gestures of people, and hence to interact appropriately with the environment. The small form factor of MUT transducers further allows their integration into smartphones and wearables.

## Project Details

**Concept**

- Addressing both SMEs and large companies with a technology platform for miniaturized MEMS ultrasonic transducers (MUTs) to serve existing as well as emerging new applications

**R&D objectives**

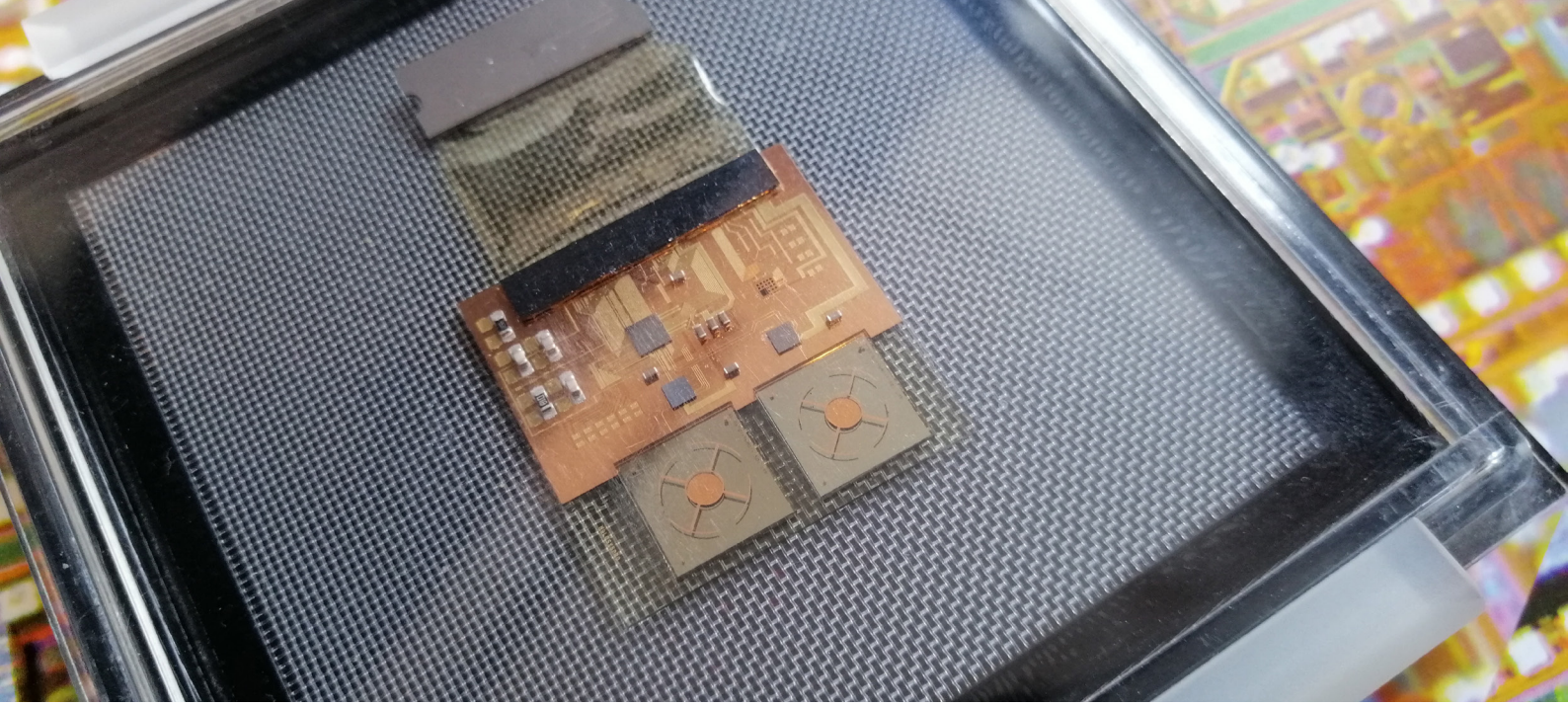
- Offering ranges from consulting to system development
- Provision of single and few channel MUTs up to high channel count MUT arrays for e.g. distance and flow measurements as well as imaging
- Customer-specific adaption of MUT system design to given application needs
- Provision of evaluation kits and advanced design tools as fast track to MUT testing in specific application

**Added value**

- Providing access to next generation miniaturized and highly integrated MUT systems
- Easy testing due to advanced electronic interfaces
- Coverage of the whole value chain from design to pilot production
- Shortened time-to-market

**Targeted applications**

- Industrial as well as health and quality-of-life applications
- Micro-positioning and adaptive gripping
- Condition monitoring and process control of media
- Imaging for medical diagnostics and therapy as well as for inspection in industry
- Analysis of body functions
- Human-machine-interaction, e.g. via gesture control



## Modular Integration of thin heterogeneous Sensor Systems

The objective of this platform is to provide technologies for the realization of heterogeneous systems for applications that require very small assembly heights (< 500 µm). The need for this arises from applications such as portable in-clothes-integrated electronics (so called wearables) as well as fiber-plastic composites with embedded electronics.

One major challenge for the realization of heterogeneous sensor systems with small assembly heights is the integration of devices using different manufacturing technologies such as: MEMS, MOEMS, integrated passive devices, evaluation electronics, and batteries. Different concepts for the modular assembly of very thin, complex sensor systems have been developed, including also the technological implementation of these concepts.

Based on this development work, various applications such as smart cards, foldable electronics, fiber compound lightweight construction and wearables, which are currently of great interest to industry, can be addressed by customer-specific R&D. Furthermore, this technology platform allows the development of wafer-level-packages as a cost-effective alternative to silicon-interposer technologies for applications that require medium-density integration.

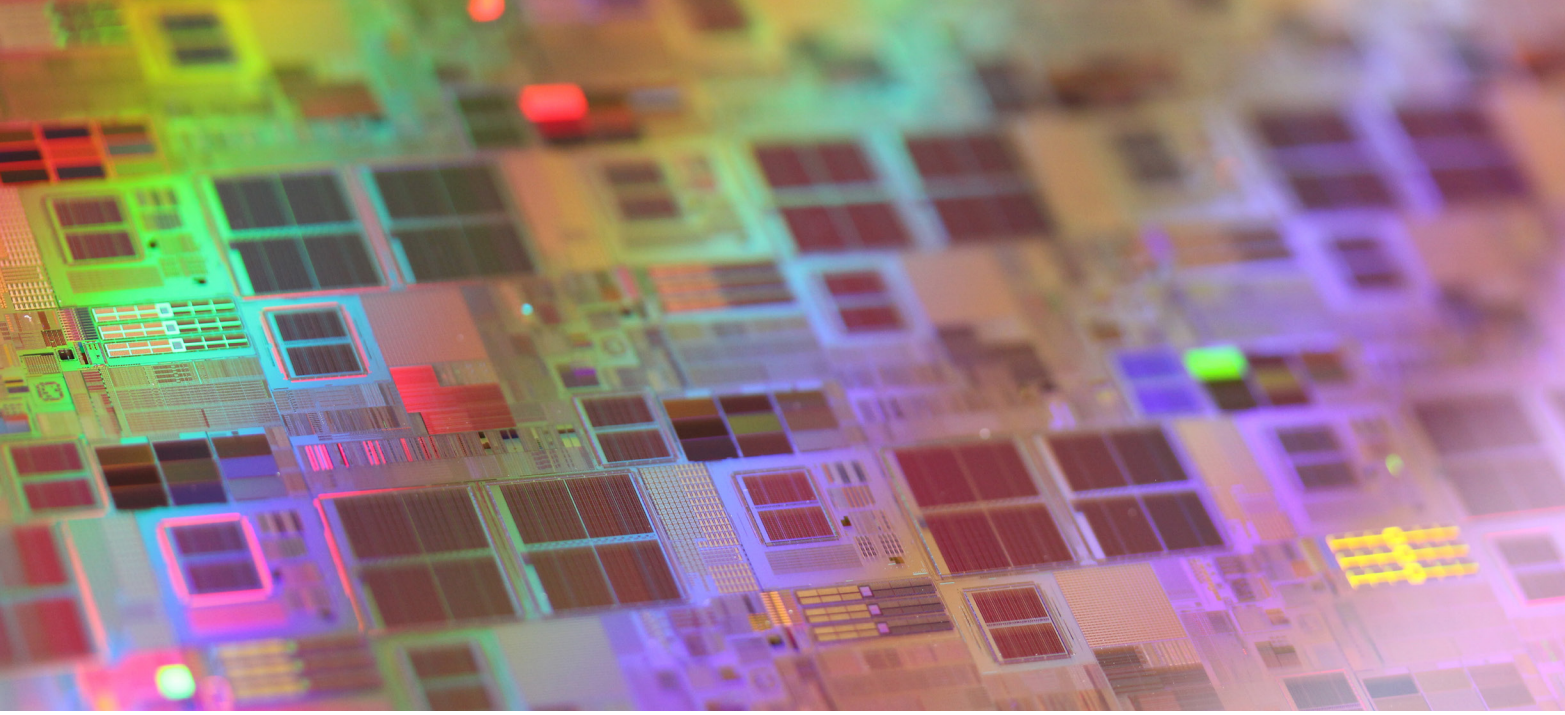
## Project Details

**Concept**
- Thin, encapsulated systems
- Modular technology for
  - Wafer-level packaging for rigid systems (wafer stacks)
  - Flexible assembly (interposer)

**R&D objectives**
- Technologies for system integration
- Miniaturization of the assembly
- Reliability studies

**Added value**
- Technology platform for thin and heterogeneous wafer-level packages
- Alternative to Si-interposer/Fan-out wafer-level-package (FoWLP) technologies for medium-density integration
- Scalability of assembly technology depending on system complexity
- Broad field of applications

**Targeted applications**
- Wearables, smart cards
- Fiber compound lightweight construction
- High performance, e.g. augmented-/virtual-/mixed-reality
- Industrial IoT



## Test Wafer Hub

Creating new products based on 300 mm silicon wafer technologies requires significant process development effort. It therefore represents a costly and time-consuming challenge when carried out in an actual production line. Thus, the availability of 300 mm test wafers and process modules, which closely mimic those used in 300 mm silicon wafer fabs, is essential for the development of new critical technology steps and components. The supplier industry, which provides tools, raw materials and consumables for the production of silicon microelectronics. The companies can also benefit from access to a test environment close to current manufacturing conditions, which allows them to pre-qualify new products prior to a presentation to customers.

The objective of the Test Wafer Hub is to provide a 300 mm test and evaluation platform. Based on their complementary resources in process technology development, analytics and application-specific know-how, Fraunhofer IPMS and IZM-ASSID jointly offer sophisticated structured test vehicles and test substrates for 300 mm CMOS or advanced packaging development. The offering covers front-end-of-line (FEoL) technologies, on the one hand and back-end-of-line (BEoL) processes as well as advanced packaging on the other hand. While the first includes high-k dielectrics and epitaxial Si(Ge) layers, the latter addresses the metallization, especially by means of copper and its embedding. The technology offering comprises also the integration of materials and structures for novel spin-based or ferroelectric memories.

## Project Details

**Concept**

- Supporting customers in process and product development by providing test wafers
- Sharing complementary skills and resources at IZM-ASSID and IPMS

**R&D objectives**

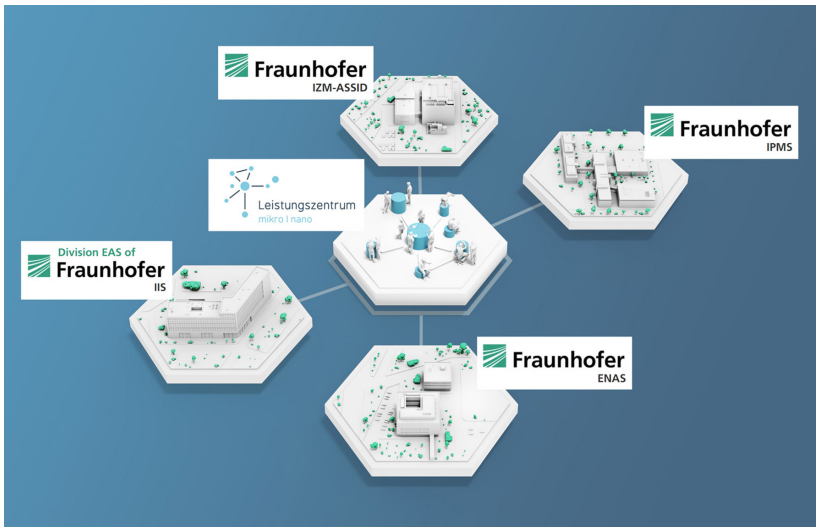
- Expanding the portfolio of current test vehicles
- Improved connection of hardware and logistic resources
- Creation of a common marketing platform

**Added value**

- Joint offer for process development by IZM-ASSID and IPMS using complementary process modules
- Offering both front-end and back-end technologies through a single point of contact
- Mutual tool backup between partners to improve delivery and reliability of products and services

**Targeted applications**

- Test wafers for the development of materials and processes for 300 mm silicon fabs
- Material-process screening and development on 300 mm wafers
- Integrated front-end and back-end technology development to reduce development time

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